GAPTEC DC-DC Railway Power Application Guide

This application note underlines the different requirements that are in use for battery powered railway applications and introduces GAPTEC's rugged railway DC-DC converters as well as application notes.

GAPTEC Electronic GmbH & Co. KG, Robert-Bosch-Straße 28, D-63225 Langen
Tel.: +49 (0) 6106 62598-100, Fax: +49 (0) 6106 62598-102, info@gaptec-electronic.com

1. Railway Power Overview

The source of power for train-borne electronic systems is the main vehicle traction battery. The battery is typically charged by an auxiliary inverter equipped with voltage regulation, but the start-up characteristics of the inverter can affect the battery output voltage. Electronic systems designed to operate on trains have to work through all of the functional variations in the supply voltage of the battery, which means there is a requirement for DC-DC converters to have wide input voltage ranges.

2. Railway Power Standards

EN 50155 is the industry standard applicable to electrical equipment supplied to the Railway Industry within Europe and a similar standard, TB/T3021 covers the requirements for train-borne electronic systems in China. Some older standards such as RIA12 in the UK are also still applicable to older rolling stock and there are cases when electronic systems need to be designed to meet these standards. The EU standard EN 50155 has been recognized by most railway equipment manufacturers. This standard is applicable to all electronic equipment installed in railway vehicles for control, adjustment, protection, and supply etc. EN 50155 relates to battery powered supply systems or low voltage power supplies that are directly connected to, or not connected to the contact system. DC-DC converters for in-vehicle electronic equipment must meet EN50155, and must satisfy the following requirements:

I. Input voltage range
II. Electromagnetic compatibility
III. Mechanical - shock and vibration
IV. Temperature and humidity
V. Isolation voltage

3. Electrical Requirements for EN50155 3.1 Input voltage range

EN 50155 covers nominal input voltage ranges for different train-borne traction batteries. The nominal battery voltages Vn are 24V, 28V, 36V, 48V, 72V, 96V, and 110V depending on the class of vehicle. All electronic equipment should be designed to operate continuously in the range 0.7Vn to 1.25Vn and to also withstand temporary fluctuations in the range 0.6Vn to 1.4Vn. All of GAPTEC's DC-DC converters suitable for the railway industry have been designed to operate continuously in the range 0.6Vn to 1.4Vn

As examples, GAPTEC's railway power DC-DC converter, 20DRW4_110yyS1.5 has an input voltage range of 40VDC~160VDC, and is compatible with 72VDC, 96VDC, 110VDC vehicle batteries. The 150HBRW4_110xxS3 has an input voltage range is 50VDC~160VDC and is compatible with 96VDC and 110VDC vehicle batteries.

GAPTEC Electronic GmbH & Co. KG, Robert-Bosch-Straße 28, D-63225 Langen
Tel.: +49 (0) 6106 62598-100, Fax: +49 (0) 6106 62598-102, info@gaptec-electronic.com

3.1.1 Rated input voltage range

Nominal Inputs (VN)	Input Ranges 0.7VN – 1.25VN	Transient	
		Low (0.1s) 0.6VN	High (1s) 1.4VN
24V	16.6 – 30V	14.4V	34V
28V	19.6-33V	16.8V	39.2V
36V	25.2 – 45V	21.6V	50.4V
48V	33.6 – 60V	28.8V	67V
72V	50.4 – 90V	43.2V	101V
96V	67.2 – 120V	57.6V	135V
110V	77 – 137.5V	66V	154V

Table 1: Input specifications for EN50155

3.1.2 Input voltage transient (RIA12 requirement)

BS railway standards RIA12 general specification of traction & rolling stock electronic equipment from transients & surges in DC control systems, is an old UK railway standard but is still applicable to equipment fitted to older railway vehicles. RIA12 requires that the electronic equipment must be able to withstand surges up to 3.5 times Vn for 20mS duration, and coming from a source impedance of 0.2Ω. The energy associated with these surges in 110V systems can be calculated by the formula:

$$W = V_N * \frac{3.5V_N - V_C}{} * t$$

= 2475J (based on a clamping voltage VC of 160VDC).

This is far too high for traditional TVS devices (typ. 1.5J) and requires either and active clamping element or a very wide input voltage range.

Voltage Waveform	Voltage Level	Duration	Source Impedance
A	$3.5V_N$	20mS	0.2Ω
B	$1.5V_N$	1S	0.2Ω

Table 2: RIA12 Waveform Parameter Requirements

GAPTEC Electronic GmbH & Co. KG, Robert-Bosch-Straße 28, D-63225 Langen
Tel.: +49 (0) 6106 62598-100, Fax: +49 (0) 6106 62598-102, info@gaptec-electronic.com

GAPTEC's EMC auxiliary devices use a series-connected active clamp circuit that limits the transient surge voltage to a voltage range that a downstream DC-DC converter can withstand.

3.1.3 Interruptions of voltage supply

Equipment designed to meet the requirements of EN50155 may be required to operate through short interruptions in the incoming supply. These can be:

- Class S1: no interruptions
- Class S2: 10mS interruptions
- Class S3: 20mS interruptions

EN50155 standards defines that an interruption may occur if the equipment supply is switched between different input sources. These can be:

- C1 100mS at 0.6VN
- C2 30mS interruption

In order to meet the requirements of Classes S2, S3 and C2 some additional energy storage is required at the input of any DC-DC converter. Most commonly this will be in the form of a capacitor and should be dimensioned according to the equation:

$$C = \frac{2*(Pout/\eta)*Time}{V_N{}^2 - V_{star}^2}$$

As an example, a 15W system needing to meet class S1 and being supplied from 110V dc by a GAPTEC DC-DC module 20DRW4_110yyS1.5 can requires an input capacitor C from the equation:

$$C = \frac{2*(Pout/\eta)*Time}{V_N{}^2 - V_{star}^2} \quad C = \frac{2*(Pout/\eta)*Time}{V_N{}^2 - V_{star}^2} = \frac{2*(15W/0.85)*10mS}{110^2 VDC - 40^2 VDC} = 33.6uF$$

Note: When considering the tolerance of electrolytic capacitors and the effects of low temperature operation it is recommended that a capacitor of 68uF can be used in this example.

GAPTEC Electronic GmbH & Co. KG, Robert-Bosch-Straße 28, D-63225 Langen
Tel.: +49 (0) 6106 62598-100, Fax: +49 (0) 6106 62598-102, info@gaptec-electronic.com

3.2 Electromagnetic compatibility requirements

The EMC requirements of train-borne electrical equipment are defined by how in interfaces with the external environment. These interfaces are known as ports:

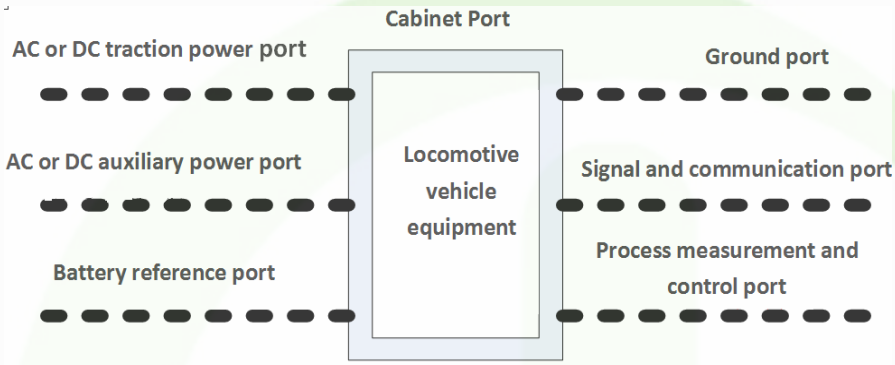

Fig.1. Locomotive Electrical Equipment Interfaces (ports)

Different ports have different EMC requirements. For battery ports, there are no conducted emissions limits in the frequency of 9 kHz~150 kHz. Table 3 shows the EMC requirements for a battery referenced port in accordance with EN50121-3-2, The same limits are also applicable to signal and communication ports as well as process measurement and control ports.

Test Items	Limits or test requirements
Conducted emissions emission <30MHz 150kHz~500kHz 500kHz~30MHz	 99dBuV quasi-peak 93dBuV quasi-peak
Radiated emissions qb at10m >30MHz 30MHz~230Mhz 230MHz~1GHz	 40dBuV/m quasi-peak 47dBuV/m quasi-peak

Table 3: EN50121-3-2 Emissions Test Requirements

GAPTEC Electronic GmbH & Co. KG, Robert-Bosch-Straße 28, D-63225 Langen
Tel.: +49 (0) 6106 62598-100, Fax: +49 (0) 6106 62598-102, info@gaptec-electronic.com

Conducted disturbance immunity IEC 61000-4-6	0,15 MHz ... 80 MHz 10 V (r.m.s) 80 % AM, 1 kHz Performance criteria A
Fast transients IEC 61000-4-4	± 2 kV, 5/50ns, 5 kHz Performance criteria A
Surge IEC 61000-4-5	1.2 / 50 µs ± 2 kV /42 Ω, 0.5µF, Open circuit test voltage, line to ground ± 1 kV /42 Ω, 0.5µF, Open circuit test voltage, line to line Performance criteria B
ESD IEC 61000-4-2	± 6 kV, Contact discharge ± 8 kV, Air discharge Performance criteria B
Radio-frequency electromagnetic field. Amplitude modulated IEC 61000-4-3	80 MHz ... 800 MHz 20 V/m(rms), 80 % AM, 1 kHz 800 MHz ... 1000 MHz 20 V/m(rms), 80 % AM, 1 kHz 1400 MHz ... 2000 MHz 10 V/m(rms), 80 % AM, 1 kHz 2000 MHz ... 2700 MHz 5 V/m(rms), 80 % AM, 1 kHz 5100 MHz ... 6000 MHz 3 V/m(rms), 80 % AM, 1 kHz Performance criteria A

Table 4. EN50121-3-2 Immunity Test Requirements

3.3 Vibration and Shock

All train-borne electronic equipment must be able to withstand, without deterioration, the levels of shock and vibration which would be seen by a train in regular service. These levels can be defined by the train supplier, but unless otherwise stated shall meet the requirements of EN61373 category 1, Class B. These are defined below:

Device Location	Performance	EN50155/IEC61373
On-board electronic	Vibration test requirements	Category<0.3Kg 5-150Hz 5g
	Shock test requirements	Long./Trans./Vert. axis 5g/3g/3g 30mS/30mS/30mS

Table 5: Vibration and Shock Requirements

All GAPTEC DC-DC converters are fully potted with an insulating epoxy resin. This provides excellent immunity against the stresses found on all rolling stock.

GAPTEC Electronic GmbH & Co. KG, Robert-Bosch-Straße 28, D-63225 Langen
Tel.: +49 (0) 6106 62598-100, Fax: +49 (0) 6106 62598-102, info@gaptec-electronic.com

3.4 Temperature/Humidity Requirements

All train-borne electronic equipment must be designed to operate to its full specification according to a range of different temperature classes, shown below in Table 6:

Class	Equipment operating temperature range
OT1	-25°C~+55°C
OT2	-40°C~+55°C
OT3	-25°C~+70°C
OT4	-40°C~+70°C
OT5	-25°C~+85°C
OT6	-40°C~+85°C

Table 6: Temperature Requirements

Classes OT1 and OT2 should be used for passenger compartments and the driver's cab with a standard reference temperature of +25°C. OT3 and OT4 can be used for equipment in technical cabinets with a standard reference temperature of +45°C. Unless otherwise specified class OT3 should be used as the default class.

GAPTEC's railway DC-DC converters are designed to operate in a convection cooled environment of -40°C to 85°C with many also able to operate in ambient temperatures up 100°C.
In order to prove compliance with the thermal and humidity requirements of EN50155:2017 there are a number of type tests which must be met by the final equipment.

Test item	Criterion
Low temperature test	EN60068-2-1 test Ad
Dry heat test	EN60068-2-2 test Be
Damp Heat Test	EN60068-2-30 test Db
Low temp. storage test	EN60068-2-1

Table 7: Environmental Test Requirements

GAPTEC railway DC-DC converters are designed and manufactured in accordance with strict quality control systems and are fully compliant with all of the tests detailed above.

GAPTEC Electronic GmbH & Co. KG, Robert-Bosch-Straße 28, D-63225 Langen
Tel.: +49 (0) 6106 62598-100, Fax: +49 (0) 6106 62598-102, info@gaptec-electronic.com

3.5 Insulation and voltage withstand requirements

These requirements ensure that components are not mounted too close to their surrounding metal cases and fixings. It will also ensure that circuits meet their galvanic insulation requirements.

The test comprises 2 parts, the first of which is the insulation resistance measurement. This is made at 500V dc. The minimum level of insulation resistance shall be 20M ohms. The second part is a voltage withstand test which is performed in accordance with table 8 below. Voltages should be increased slowly (typ. 10 seconds) up to the maximum value and then held for 1 min in type tests and 10 seconds in routine tests.

Vehicle Battery	Isolation Requirement
24V	500VAC/50Hz 750VDC
48V	500VAC/50Hz 750VDC
72~125V	1000VAC/50Hz 1500VDC
125VDC~315V	1500VAC/50Hz 2200VDC

Table 8: Voltage Withstand Test Requirements

4. Other requirements 4.1 Redundancy

In order to increase the reliability of electronic systems, it is often a requirement to build redundancy into the power distribution system. This can be achieved with many GAPTEC modules, but we advise contacting our technical team who will give you the best advice in building this into your system.

4.2 Input reverse polarity protection

Some safeguards must be taken to ensure that installers cannot reverse connect the power cables to any equipment. Vehicle batteries have a very large energy capacity and reverse connections can often lead to short circuits. This can cause fires in the electric cabling and even damage the vehicle battery, affecting other equipment. Users must ensure that there are either electrical or mechanical measures in place which mitigate the effects of reverse polarity connections.

5. GAPTEC Railway Power Overview

GAPTEC railway power are designed to meet the requirements of EN 50155:2017. They feature compact size, low ripple & noise, excellent EMC performance and are all suitable for 24V, 48V, 72V, 96V and 110V railway traction batteries. GAPTEC's DC-DC converters also include protections

GAPTEC Electronic GmbH & Co. KG, Robert-Bosch-Straße 28, D-63225 Langen
Tel.: +49 (0) 6106 62598-100, Fax: +49 (0) 6106 62598-102, info@gaptec-electronic.com

against input under-voltage, output over-voltage, over current and external short circuits. The table below summarizes the input voltage range of GAPTEC DC-DC railway converters and EMC filters.

Typical applications of GAPTEC railway power includes:

- Air-conditioning systems
- Automated train control systems
- Ventilation and traction systems
- Passenger information
- Business class seats
- Door controls
- Braking systems
- Radio
- Lighting

GAPTEC Electronic GmbH & Co. KG, Robert-Bosch-Straße 28, D-63225 Langen
Tel.: +49 (0) 6106 62598-100, Fax: +49 (0) 6106 62598-102, info@gaptec-electronic.com